A new Dividing Engine.   By G. T. McCaw, M.A.
(Plate 13.)

About four years ago a dividing engine was constructed in South London by Messrs. E. R. Watts & Son. The constructors recently submitted a 55 cm. circle divided on this machine to the Charlottenburg Technical Institute. The result of this test may not be without interest to many members of the Society.

A few details of the machine may be given.

The main frame is of cast iron, while the revolving table is of phosphor bronze; the central spindle is of phosphor bronze, fitted in collars of oil-hardened steel. The fitting of the latter was done at the Whitworth Works, and the resultant eccentricity was subsequently found to be exceedingly small; all the rest of the machine was constructed by the owners themselves. The revolving table weighs about five cwt., and the whole engine two tons.

After the revolving table was in position, three silver rings were inlaid on the circumference of the upper face. The circle was first hand-divided, and then this graduation was tested with seven micrometers. The resultant errors were used for recutting the *traits,* and these were again tested for error. This adjusting process was continuously repeated for five months, until the micrometers indicated that none of the 4320 *traits* exhibited a greater error that $0''\cdot6$.

This graduation was now utilised for cutting the peripheral teeth of the revolving table, which engage the endless screw of the rotating gear. Every tooth was cut only after the V-cutter had been adjusted from the mean reading of the seven micrometers. Under all circumstances the temperature is kept as constant as possible, the engine being placed in a specially constructed room.

The engine is operated from a public electrical supply, and in cutting ordinary small circles for theodolites the working is entirely automatic. For the division of finer circles, the work is carried on during those periods of the day when the voltage is nearly constant, as changes of potential would slightly affect the accuracy of the graduation.

The engine will divide circles of from 3 in. to 4 ft. 6 in. diameter. The range of graduation extends from less than 1 minute up to 30 minutes of arc. Unlike some other constructors, this firm believes in dividing continuously; they are of opinion that the other system would involve more risk of error, due to local changes of temperature in the graduating-room.

The dividing can be controlled cut by cut, so that if slight inaccuracies in the peripheral teeth or endless screw or other part of the machine are proved productive of regular errors at certain parts of the circle, these errors may be mechanically eliminated.

The results of the examination at Charlottenburg are given in the table below. In this table the figures are so arranged that the sum of the errors of the thirty divisional lines, the numbers of which are successive multiples of 12, is zero. These thirty lines

Deg.	Error.	Deg.	Error.	Deg.	Error.	Deg.	Error.	Deg.	Error.	Deg.	Error.	Deg.	Error.
0	+0″.1	52	−0″.4	104	+0″.1	156	−0″.3	208	+0″.6	260	−1″.0	312	−0″.2
1	0.0	53	−0.8	105	−0.1	157	−0.4	209	+1.0	261	−1.5	313	−0.2
2	0.0	54	−0.5	106	−0.1	158	−0.2	210	+0.9	262	−1.0	314	−0.3
3	+0.3	55	−0.1	107	+0.2	159	−0.1	211	+1.1	263	−1.7	315	−0.6
4	+0.1	56	−0.3	108	0.0	160	−0.2	212	+0.9	264	−0.8	316	−0.4
5	+0.5	57	−0.6	109	+0.4	161	+0.1	213	+1.2	265	−0.4	317	−0.7
6	+0.3	58	−0.5	110	+0.7	162	−0.1	214	+0.3	266	−0.2	318	−1.0
7	+0.1	59	+0.4	111	+0.4	163	−0.4	215	+1.5	267	−0.7	319	−0.5
8	+0.5	60	−0.2	112	0.0	164	−0.7	216	+0.6	268	−0.5	320	−0.5
9	+0.4	61	−0.2	113	−0.2	165	−1.3	217	+0.6	269	−0.1	321	−0.5
10	−0.6	62	−0.1	114	+0.2	166	−1.2	218	+0.5	270	−0.2	322	−1.0
11	+0.3	63	−0.4	115	−0.2	167	−1.1	219	+0.8	271	−0.3	323	−1.2
12	+0.1	64	−0.4	116	0.0	168	−1.6	220	+1.1	272	+0.1	324	−0.8
13	0.0	65	−0.2	117	−0.2	169	−1.6	221	+0.2	273	−0.2	325	−1.0
14	−0.2	66	+0.3	118	+0.2	170	−1.0	222	+0.7	274	+0.2	326	−0.6
15	−0.5	67	+0.5	119	+0.1	171	−1.6	223	+1.0	275	+0.4	327	−0.7
16	−0.3	68	−0.4	120	0.0	172	−0.7	224	+0.5	276	+0.4	328	−0.8
17	0.0	69	−0.5	121	+0.3	173	−1.0	225	+0.7	277	−0.3	329	−0.7
18	−0.2	70	−0.1	122	+0.4	174	−1.1	226	+0.2	278	+0.5	330	−0.9
19	−0.1	71	−0.3	123	+0.2	175	−1.3	227	+0.2	279	+0.3	331	0.0
20	−0.2	72	−0.3	124	+0.3	176	−1.0	228	+0.5	280	0.0	332	−0.5
21	+0.2	73	+0.2	125	0.0	177	0.0	229	+0.6	281	+0.2	333	−0.8
22	−0.1	74	+0.5	126	+0.1	178	0.0	230	+0.3	282	−0.5	334	0.0
23	+0.1	75	+0.4	127	+0.1	179	+0.3	231	+0.6	283	−0.3	335	−0.3
24	+0.1	76	+0.3	128	+0.2	180	0.0	232	+0.1	284	−0.8	336	−0.4
25	0.0	77	+0.6	129	+0.5	181	−0.5	233	0.0	285	−0.8	337	+0.3
26	+0.1	78	+0.6	130	+0.5	182	−0.6	234	0.0	286	−0.2	338	+0.5
27	+0.5	79	+0.9	131	−0.1	183	−0.7	235	−0.2	287	0.0	339	+0.7
28	+0.7	80	+0.5	132	−0.1	184	−0.8	236	−0.1	288	+0.2	340	−0.1
29	+0.7	81	+0.3	133	−0.1	185	−0.4	237	−0.2	289	−0.3	341	+0.1
30	+0.5	82	+0.6	134	−0.5	186	−0.6	238	+0.3	290	−0.5	342	+0.2
31	+0.5	83	+0.3	135	−1.0	187	−0.6	239	+1.0	291	−0.6	343	−0.5
32	+0.1	84	−0.2	136	−0.9	188	+0.2	240	+0.4	292	−0.7	344	+0.1
33	+0.3	85	−0.1	137	−0.5	189	0.0	241	+0.7	293	−0.2	345	−0.7
34	+1.3	86	−0.1	138	−0.9	190	−0.5	242	+0.9	294	−0.2	346	−0.9
35	+1.4	87	−0.3	139	−0.9	191	−0.1	243	+1.3	295	+0.1	347	−0.4
36	+1.3	88	+0.4	140	−0.6	192	−0.1	244	+0.7	296	−0.4	348	−0.8
37	+1.8	89	0.0	141	−0.7	193	−0.9	245	+1.0	297	−0.4	349	−0.8
38	+1.5	90	−0.3	142	−1.0	194	−0.6	246	+1.5	298	−0.9	350	−0.7
39	+1.3	91	−0.3	143	−0.5	195	−0.7	247	+0.8	299	−1.0	351	−0.7
40	+0.9	92	+0.2	144	−0.4	196	−0.6	248	+0.8	300	−0.5	352	+0.4
41	+0.4	93	+1.0	145	−0.3	197	−0.2	249	+1.1	301	−0.3	353	+0.2
42	+0.6	94	+0.9	146	−0.3	198	0.0	250	+1.5	302	−0.7	354	+0.6
43	+0.5	95	+0.8	147	+0.2	199	−0.2	251	+1.5	303	−0.8	355	+0.2
44	+0.6	96	+0.6	148	−0.4	200	+0.1	252	+1.1	304	−1.0	356	−0.2
45	+0.5	97	+0.1	149	−0.3	201	−0.2	253	+0.4	305	−0.6	357	+0.3
46	+0.6	98	+0.4	150	−0.6	202	−0.2	254	+0.5	306	−0.5	358	+0.2
47	+0.1	99	+0.6	151	−0.5	203	−0.1	255	+0.8	307	−1.0	359	+0.4
48	+0.7	100	+0.2	152	+0.1	204	+0.6	256	+0.4	308	−1.1	360	+0.1
49	+0.2	101	0.0	153	−0.1	205	+0.7	257	+1.0	309	−1.0		
50	0.0	102	0.0	154	−0.1	206	+0.3	258	−0.1	310	−0.2		
51	−0.5	103	+0.2	155	−0.8	207	+1.3	259	−0.4	311	−0.8		

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form the basis for the fundamental examination, and the remaining values are inserted between them.

The figure-values indicated are reliable for the thirty fundamental lines to about $\pm 0''\cdot3$, for the remaining lines in the average to about $\pm 0''\cdot5$.

An analysis of the table of error shows that the range is $+ 1''\cdot8$ to $- 1''\cdot7$. From $0°$ to $180°$, only 14 errors exceed $1''$; from $180°$ to $360°$, 16. The first $180°$ contain 50 errors greater than p.e. of observation; the second $180°$, 90 errors of this kind; in all, 39% of the errors are less than the p.e. of observation. As regards sign, 155 are *plus* and 180 *minus*.

These results seem to indicate that the limit of accuracy is closely approached; yet we understand the constructors have in view new schemes for improving the division. The greater errors appear in seven well-defined groups, and it is to the elimination of these greater errors that attention should be directed, as most of the others are either admittedly within the p.e. of observation, or so very nearly so that their removal would be barely possible.